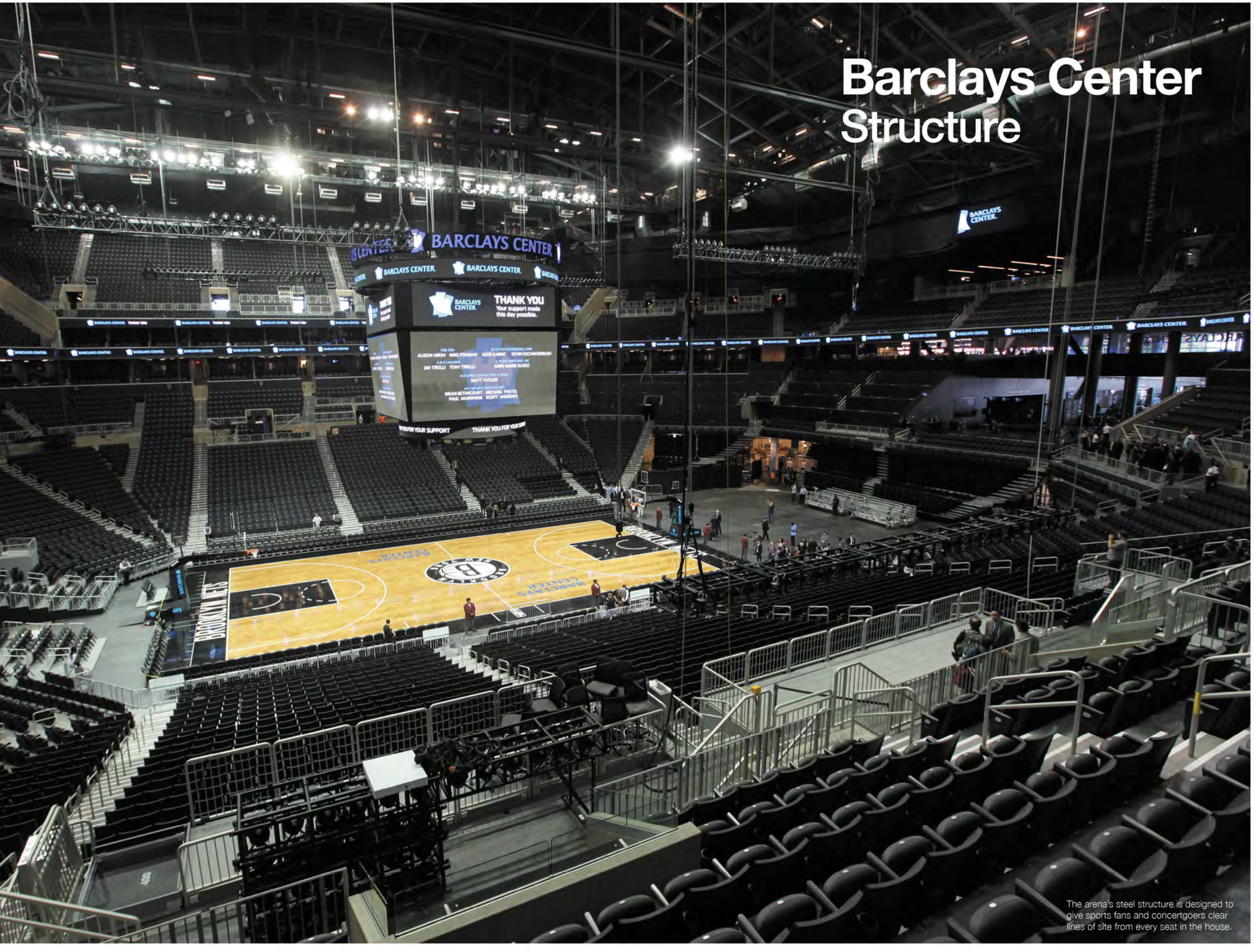
Barclays Center Structure



The arena's steel structure is designed to give sports fans and concertgoers clear lines of site from every seat in the house.

Brooklyn's new multi-purpose indoor arena relies on a structural steel geometry that will keep visitors coming back time and time again.

WHEN TICKETHOLDERS ARRIVED for the series of Jay-Z concerts that officially opened Brooklyn's new Barclays Center on September 28, they were treated to a dramatic view of the lighting cluster above the stage from the moment they walked onto the Center's main entrance plaza. The design team intentionally planned this experience so visitors could visually connect with the massive arena's interior while still outside at the corner of Atlantic and Flatbush avenues. Not only would this help them find their way into the building, but glimpses of the three-story, 70,000-pound central scoreboard would pump up fans on game days.

This seemingly simple gesture, which creates a quintessential only-in-New York street scene, relies in large part on several structural engineering maneuvers that nestled the 675,000-square-foot arena into its site on the northwest corner of the 22-acre Atlantic Yards development. As a result, unlike several new arenas developed in the last decades in other American cities, the scale of the Barclays Center does not appear to overwhelm its site. This was a critical gesture for Forest City Ratner Companies (FCRC), the Barclays' developer that had famously struggled to win community support for the overall development.

The seating bowl of the arena, which rises from approximately 30 feet below street grade and makes these visual connections possible, has similar sightlines to those of Indianapolis's Bankers Life Fieldhouse. That project, which like the interior of the Barclays was designed by Ellerbe Becket Architects and Engineers (now AECOM), relied on a concrete superstructure and steel roof trusses. SHoP Architects designed the exterior of the Barclays, as well as some interior architecture components (see the story about the Barclays Center facade on page 22 of this issue). "Everything in the design of an arena evolves from the bowl design," says Steve Duethman, AECOM's project manager for the Barclays: Ticket price points, luxury suites, and other requirements of the 19,000-seat arena all rely on the geometry set by the bowl.

Structural engineers at New York's Thornton Tomasetti (TT) developed a modified version of the

Above and left Precast concrete stadia units span between steel rakers.
Far left The steel erection sequence minimized strain compatibility between elongation of the roof structure's tension tie and the superstructure's lateral displacement.

Bess Adler/Thornton Tomasetti; facing page top and center: Bess Adler/Thornton Tomasetti; facing page bottom: Banker Steel; opening spread: Bruce Damonte

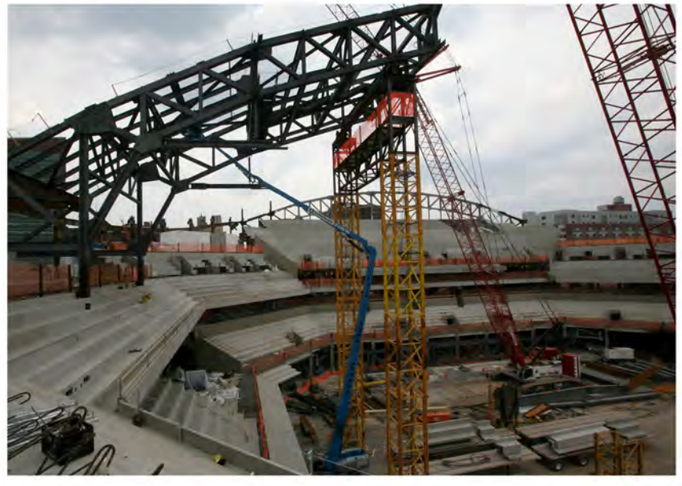
This page A tied-arch roof truss forms the 350-foot-long span of the stadium's roof. Structural engineer Thornton Tomasetti designed the connections at each end of the truss to transmit some lateral forces to the superstructure.

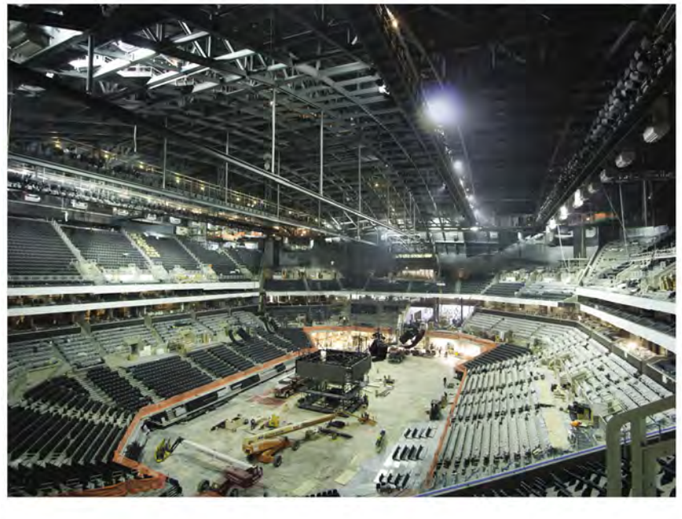
Indianapolis arena's structure for Brooklyn's project. Jeff Callow, TT's project manager for Barclays', says although the Indianapolis project provided a time-saving template, the congested site at Barclays, as well as market considerations, led the team to adopt a steel structure. This eliminated the potential scheduling challenges of having too many trades on the site at once. The primary differences between the Brooklyn structure and Indianapolis are the use of a tied-arch roof truss system, rather than a more conventional arched truss, a steel superstructure rather than concrete, and precast concrete stadia units spanning between steel rakers, as opposed to cast-in-place units.

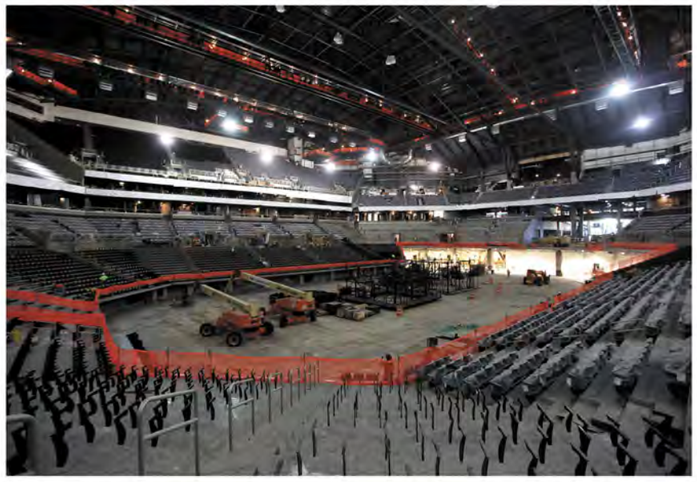
Callow says the tied-arch system was used as an efficient means to achieve the 350-foot-long span of the roof. The Indianapolis arena resolved arch thrust forces using the lateral stiffness of the concrete superstructure. Due to the relatively tight urban site of Barclays, the design-build team determined it was preferable to construct the entire superstructure from steel to limit activity to one construction trade on site during the erection sequence. However, Callow says that, given the limited real estate on which to build, steel structure would not inherently have sufficient lateral stiffness to resist the arch thrust forces alone. By introducing the tension tie to balance the arch forces, the thrust forces imposed on the superstructure are greatly minimized.

Two main tied-arch trusses run in the long east-west direction, spanning approximately 350 feet. Each comprises a 12-foot-6-inch-deep arched upper truss, with chords made up of W14s that vary across the section and a tension tie, consisting of a 14x311 wide-flange member, which occurs approximately 50 feet below the top of the arched truss and 10 feet above the lower ends of the truss owing to the demands of sight-line preservation. The truss configuration was largely dictated by the limitations of shipping the trusses from the fabricator. The tie is hung by a series of eight, 8-inch vertical HSF pipes. Sixteen smaller trusses connect with the large longitudinal trusses and provide the free span of the arena with chord sizes varying from 14x90 to 14x159. Dead loads and lateral loads are resolved into the steel superstructure, with thrust forces from the trusses largely balanced by the ties.

Callow says one of the project's main structural challenges was connecting the tied arch to the steel superstructure that rings the Barclays and forms







This page The building team's use of Tekla to model the structure in 3-D and troubleshoot connection details contributed to a low overall number of RFIs.
Facing The arena's 70,000-pound central scoreboard is visible to pedestrians from the corner of Atlantic and Flatbush avenues.

its street-side concourse. In a conventional design, where the tension tie would connect at the ends of the truss, the truss would rest on a roller or bearing support that could allow the truss some movement. However, in the case of Barclays, the connection had to be able to transmit some lateral forces to the superstructure. While the introduction of the tension tie significantly reduces the amount of thrust imposed on the superstructure, but does not eliminate it completely due to strain compatibility between the tension tie elongation and the superstructure lateral displacement. To minimize this effect, TT specified a construction sequence involving leave-outs of elements to disengage the arch thrust resistance of the superstructure for de-shoring of the roof structure. This forced the tied-arch action to resist the initial dead load. After the roof was de-shored, these leave-out connections were completed, leaving the superstructure to resist thrust forces under future environmental and live load conditions.

Live loads are chiefly snow, which is prevented from sliding onto the sidewalk by a series of 16-by-16-inch tube steel members, approximately 1-inch off the roofing membrane, that form fences to spread the snow across the otherwise conventional built-up roof. A total of over 10,500 tons of ASTM A992 Grade 50 structural steel is used in the project, in addition to the 600 tons of steel used for the weathered steel panels on the facade.

Aside from the usual ice rink floor to support hockey games and entertainment events on top of a fairly conventional 6-inch slab on grade, the arena's interior includes an exceptional internalized loading dock on the basement level (approximately 30 feet below grade) that relies on elevators and a massive 180-degree turntable to get trucks in and out of the arena. The relatively cramped site meant a conventional street-level ramp to a loading dock could not be accommodated. Two truck elevators, with a capacity of 80,000 pounds each, serve in the same capacity as ramps, freeing up ground-level space for street-facing retail and large expanses of glass that make the Barclays feel more a part of Brooklyn's bustling downtown. And although the center abuts nearby tunnels for New York's subway system, no special structural accommodations had to be made outside of construction-stage shoring.

An 85-foot cantilevered canopy over the main entrance represented a last-minute challenge to the structural design. To support the added loads, Thornton Tomasetti designed two 12-foot-6-inch-deep primary trusses on each side and then laced them together with diagonals to create boxed trusses that tie back to the superstructure columns at the edge of the arena bowl.

In spite of the complicated design, Callow estimates only ten or so structural RFIs for the project. This was due, in part, to working directly for Hunt Construction, but also to TT's use of sophisticated modeling and design software, particularly Tekla for 3D modeling and connection details, SAP2000 for analysis, and RAM Structural System for floor framing. An integrated design and construction team approach saved much time by short-circuiting questions regarding connections and structural cambers that could reduce overall steel tonnage. The project is currently pursuing LEED Silver certification for new construction, but the success of recent concerts and the inaugural Brooklyn Nets basketball season has quickly made the Barclays seem as if it were always there, ready for New York to walk inside.

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Bess Adler/Thornton Tomasetti; facing page: Bruce Damonte

BARCLAYS CENTER STRUCTURE

Location: **620 Atlantic Avenue, Brooklyn, NY**
Owner/Developer: **Forest City Ratner Companies**, *Brooklyn, NY*
Lead Architect: **AECOM**, *New York, NY*
Design Architect: **SHoP Architects**, *New York, NY*
Structural Engineer: **Thornton Tomasetti**, *New York, NY*
Mechanical Engineer: **WSP Flack & Kurtz**, *New York, NY*
Construction Manager: **Hunt Construction**, *Brooklyn, NY*
Curtain Wall Consultant: **Front Inc.**, *New York, NY*
Structural Steel Erector: **James F. Stearns Co., Inc.**, *Pembroke, MA*
Miscellaneous Iron Erector: **Berlin Steel**, *Kensington, CT*
Architectural and Ornamental Metal Erector: **Harriott Contracting**, *Columbia, MD*
Curtain Wall Erector: **Egan Architectural**, *Yonkers, NY*